Tule River Reservation Protection Project

Fire, Fuels, and Air Quality Report

Sequoia National Forest /Giant Sequoia National Monument

Western Divide Ranger District

Prepared by:______________________________ July 29, 2014

David Ernst

District Fuels Specialist
Western Divide Ranger District

Contents

Introduction

The Tule River Reservation Protection Project was proposed under the Tribal Forest Protection Act of 2004 by the Tule River Indian Reservation Tribe (Tribe). The main concern of the Tribe is the unnaturally high accumulations of vegetative fuels currently throughout the project area, posing a significant wildfire threat to the adjoining Tribal community and forest resources. A destructive wildfire, coming from the Giant Sequoia National Monument of the Sequoia National Forest and crossing the northern boundary of the Reservation, has the potential to damage natural and cultural resources within the South Fork of the Tule River's watershed. This watershed is considered critical to the Tribe and the loss of water quality could be devastating. In response to this proposal, the staff from the Western Divide Ranger District of the Sequoia National Forest and the Tribe worked collaboratively to identify potential management opportunities to increase protection from an unwanted wildfire. The proposal submitted by the Tribe also recognized that the project could "complement similar projects that are planned on Tribal lands located immediately to the south (Tule River Tribal Council Project Proposal, 2005, p. 3). These potential management opportunities were then presented, both on field trips and during scoping, to the Tribe, public and other agencies. Based on the comments received during scoping and current management direction, two action alternatives were developed.

This report describes the existing conditions, in terms of fuel and fire behavior, and compares them to post treatment conditions for the two proposed action alternatives. It shows the effectiveness of the fuel treatments in terms of fire activity, flame lengths, rates of spread, and firefighting suppression efforts. Total smoke emission estimates are listed for each alternative. The daily smoke emissions can be adjusted to by segmenting the project to prevent significant impacts to smoke sensitive areas or exceedences of 24 hour standards.

Location

The Tule River Reservation Protection (TRRPP) Project area is approximately 2,840 acres on National Forest System lands and is approximately ten air miles east of the Western Divide Ranger District office in Springville, California. There are 265 acres of private property in four separate parcels in the project area. These acres are not included in the project acreage calculations

The project area is located along the northern boundary of the Tule River Indian Reservation (Reservation). The project area is within the Tribal Fuel Emphasis Treatment Area designated under the 2012 Giant Sequoia National Monument Management Plan (USDA 2012) and overlaps a portion of the Black Mountain Giant Sequoia Grove overlaps a portion of the Black Mountain Giant Sequoia Grove. The project area boundaries are:

200 feet past Forest Service Road 21S12 on the west and north;

200 feet past Road 21S94 in the east;

and the boundary between the Forest and the Reservation on the south.

The project area lies along the upper third of the slope on the north aspect of the ridge dividing the Middle Fork and the South Fork of the Tule River. The elevation range is from 4,800 to 7,300 feet.

Proposed Action

The proposed action is to reduce surface and ladder fuels on approximately 1,400 acres using a combination of treatments. These treatments include constructing shaded fuel breaks along ridgelines, private land boundaries and road edges; reducing fuels in planted areas; and prescribed burning in a portion of these and additional areas using jackpot burning, pile burning and understory burning techniques.

Issues

Scoping responses from the public, other agencies, and the Tule River Tribe were used to formulate issues concerning the proposed action. The Forest Service separated the issues into two groups: significant and non-significant. Significant issues were defined as those directly or indirectly caused by implementing the proposed action. Non-significant issues were identified as those: 1) outside the scope of the proposed action; 2) already decided by law, regulation, Forest Plan, or other higher level decision; 3) irrelevant to the decision to be made; or 4) conjectural and not supported by scientific or factual evidence. The Council on Environmental Quality (CEQ) NEPA regulations explain this delineation in Sec. 1501.7, "...identify and eliminate from detailed study the issues which are not significant or which have been covered by prior environmental review (Sec. 1506.3)..." A list of issues and reasons why they were found non-significant may be found in the project record on file at the Western Divide Ranger Station.

The Forest Service identified the following issues during scoping:

Abundance of Snags: There is a concern that the proposed action would not treat enough snags to be effective in reducing fire spread, or that the proposed action would treat too many snags:

The Proposed Action does not treat a sufficient number of snags along Forest Service Roads 21S94 and 21S12 to be effective in reducing the risk of fire spread and to provide firefighters with a safe, effective area to fight fires.

The proposed action is inconsistent with the inventory information that says the project area has an 'excessive number of snags' and snags should be retained, even if they occur in clumps.

Both comments include recommendations to consider adding a snag guideline as part of the treatment for the Tule River Reservation Protection Project. *The key indicator for this issue is average snags per acre.*

Woody Debris Concentrations: Concern that the Proposed Action fuel treatments along Forest Roads 21S94 and 21S12, which are mid-slope, would not provide enough of a barrier to fires burning upslope from the Tule River due to steep terrain, heavy fuel loads and lack of safety zones and retreat routes.

The key indicator for this issue is tons per acre of woody debris. Alternative 3 is designed, in part, to respond to this issue.

Private Land: Concern that the Proposed Action is not effective in reducing fire spread from the private lands because fuel loads are quite heavy and that the terrain is quite steep, especially in the upper end of Wilson Creek and near Bateman Ridge, Simmons Post Camp, Camp Nelson, Rogers Camp and Mountain Aire.

The key indicator for this issue is acres of fuel reduction treatment. Alternative 3 is designed, in part, to respond to this issue.

Management Direction associated with Fire and Fuels Management

The Proposed Action and alternatives are guided by the legislative authorities for administration of the National Forest System vegetation and fuels management programs; which are listed in Forest Service Manuals 2020 and 5150, respectively (USDA 2011a and USDA 1991a). Objectives, policies, and responsibilities for ecological restoration and fuels management are in FSM 2020 and FSM 5150, respectively:

The objective is to "reestablish and retain ecological resilience of National Forest System lands and associated resources to achieve sustainable management and provide a broad range of ecosystem services." (FSM 2020)

The objective is "to identify, develop, and maintain fuel profiles that contribute to the most cost-efficient fire protection and use program in support of land and resource management direction in the forest plan." (FSM 5150.2)

The Forest Service Handbook (FSH) 2409.19, Chapter 60 provides direction regarding the Tribal Forest Protection Act. Specifically, the handbook allows contracts or agreements to carry out projects to protect Indian forest lands.

The applicable management direction is currently reflected in the 2012 Giant Sequoia National Monument Management Plan (Monument Management Plan) (USDA 2012).[1] The desired conditions, strategies and objectives for fire, fuels and air quality related to this project are listed below:

Fire and Fuels desired condition is (2012 Monument Plan p. 24):

Fire occurs in its characteristic pattern and resumes its ecological role. Frequent fire maintains lower, manageable levels of flammable materials in most areas, especially in the surface and understory layers. There is a vegetation mosaic of age classes, tree sizes, and species composition, and a low risk for uncharacteristic large, catastrophic fires. The objects of interest are protected; sustainable environmental, social, and economic benefits (such as those associated with tourism) are maintained; and the carbon sequestered in large trees is stabilized.

Air Quality desired condition is (2012 Monument Plan p. 24):

Emissions generated by the Monument are limited and managed, and clean air is provided for the Monument and surrounding communities.

Strategies and Objectives Related to Fire and Fuels

Strategies for Climate Change/Carbon Sequestration (2012 Monument Plan p. 45):

Improve the potential for forest ecosystems to return to desired conditions following natural disturbances, such as through the use of prescribed fire, managed wildfire, or mechanical treatments to reduce ladder fuels or tree densities (Strategy 6).

Strategies for Fuels Reduction (2012 Monument Plan p. 48):

Prioritize treatments for fuels reduction and ecological restoration by land allocations/management areas as follows (Strategy 10):

1. WUI defense zone
2. Tribal fuels emphasis treatment area (TFETA) areas of high and moderate fire susceptibility within 1/4-mile of the reservation boundary (fig. 1)
3. WUI threat zone
4. Giant sequoia groves (not previously treated in 1 through 3)
5. TFETA areas of high fire susceptibility (not previously treated in 2)
6. Old forest emphasis areas (not previously treated in 1 through 5)

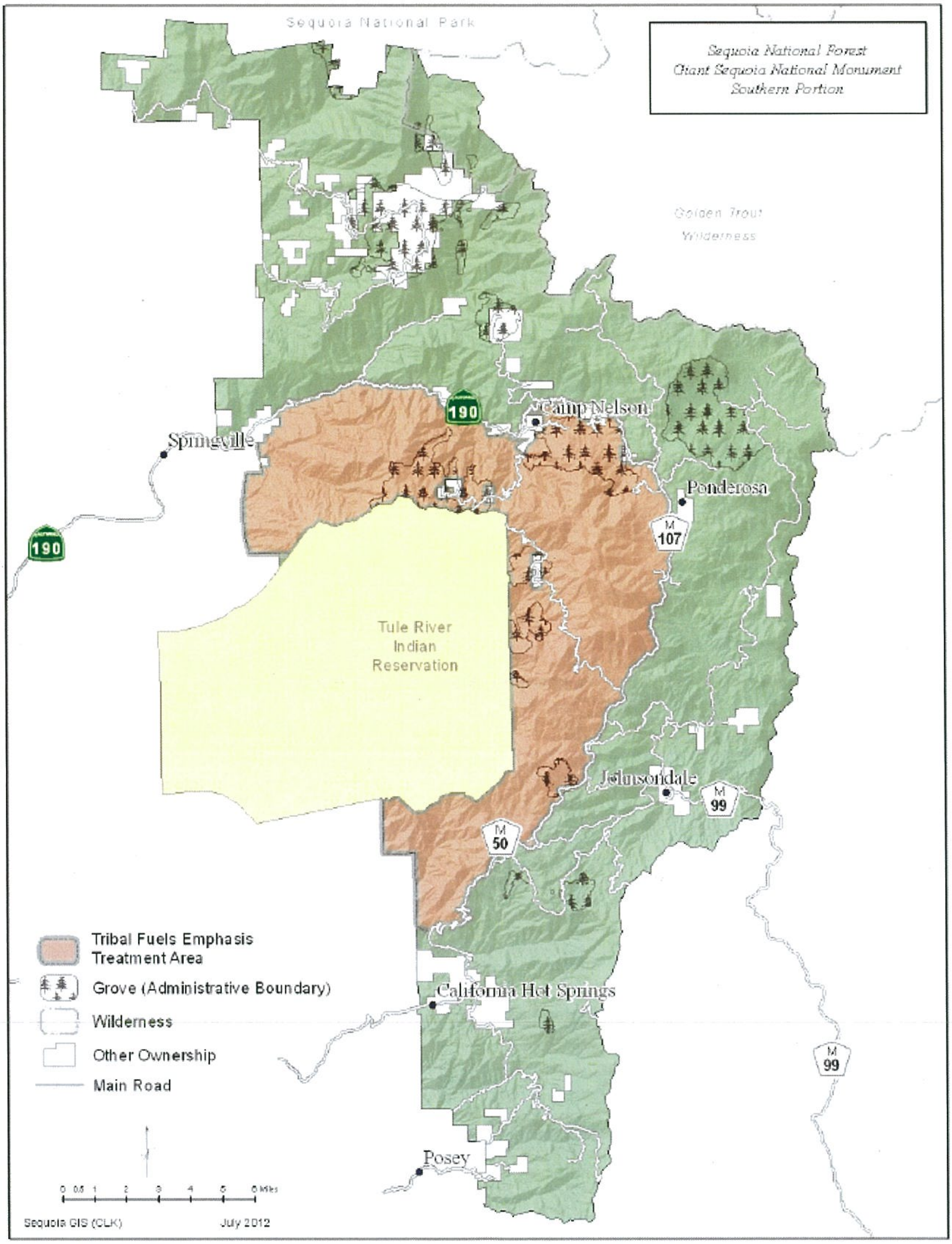
Focus fuel treatments in the TFETA to slow the spread of fire and to protect the objects of interest in the Monument, the reservation, and their watersheds from severe fire effects. The first priority for fuel reduction treatments in the TFETA is those areas within 1/4 mile of the reservation boundary with high and moderate fire susceptibility, and in the Long Canyon area. (Strategy 12).

Use the following tools for fuels reduction, in order of priority: prescribed fire, mechanical treatment, managed wildfire (when available) (Strategy 13).

Allow low, moderate, and high intensity fires to burn in the Monument, including within giant sequoia groves (Strategy 14).

Provide a minimum 100-foot defensible space (CFR Section 4291) for all structures on administrative sites, structures authorized by permit, and for developments adjacent to National Forest System lands (Strategy 15).

Figure 1--Tribal Fuels Emphasis Treatment Area



Affected Environment / Existing Conditions

Fuel

The vegetation in the project area is comprised predominately of mixed conifer tree species and other plants associated with the Southern Sierra Nevada range. The overstory and understory canopy layers include a mix of conifers, hardwoods and giant sequoias. Understory vegetation is comprised primarily of woody shrubs and forbs including, bear clover, manzanita, white thorn and chinquapin.

The mixed conifer forests within Sierra Nevada Mountains prior to European settlement were thought to be uneven-aged, patchy, broken, and diverse in vegetation. Fire ignited by lightning and Native Americans prevented the accumulation of dead and live fuels that supported unnatural high intensity stand replacing wildfires (Mckevy et al. 1996). Low to moderate intensity fires burned regularly and frequently, favoring fire resistant and dependent species by removing duff, litter and understory plants. However, grazing, logging, mining, recreation and, most importantly, fire suppression have influenced patterns in Sierra Nevada ecosystems over the last century. Little of the higher elevation zones have burned due to effective suppression of the low to moderate intensity fires (Skinner and Chang 1996). One direct consequence of these changes is an increased hazard of wildfires sweeping through groves with a severity that was rarely encountered in pre-Euro-American times (Kilgore and Sando 1975, Stephens 1998).

The lack of fire in the last century has modified the structure of mixed-conifer forests of the southern Sierra Nevada. (Parsons and DeBenedetti 1979, Bonnicksen and Stone 1982). The density of small shade-tolerant trees and high surface fuel loads has increased the hazard of extreme fire behavior (Kilgore, 1973, Van Wagtendonk 1985). The horizontal and vertical fuel continuity has also increased, resulting in forests that are vulnerable to loss and damage (Stephens 1998). Similar situations were found in the Fuel Load Reduction Plan for the Black Mountain Giant Sequoia Grove in 2013 (USDA Forest Service) and the Black Mountain Grove inventory of 2004 (Jump) within the perimeter of the project area.

Fuel inventories conducted in 2003 found that the Black Mountain Grove is in a declining state of health due to decades of wildfire exclusion. The overstocked stands are causing density-related mortality. The competition for soil moisture, sunlight, and nutrients is resulting in declining tree growth rates and a shift in the species composition away from shade-intolerant species; such as ponderosa pine, sugar pine, and giant sequoia; toward shade-tolerant species; such as white fir. The Grove Fuel Plan indicates that there is a heavy fuel load, coupled with dense ladder fuels, in the Black Mountain Grove that makes the grove at a high risk of loss from a stand-replacing wildfire. In 2003, the grove averaged 35 snags per acre (21 tons) and 39 down logs (49 tons) per acre, which is nearly five times the desired amount as described in Jump (2004). About two-thirds of the 35 snags per acre are trees have died within the past 10 years prior to the inventory. Across all size classes, the fuel loading is currently 92 tons per acre (Table 1). Since the 2003 inventory, shade tolerant tree species have continued to dominate within the grove, leading to even greater fuel loading.

To provide an area for suppression forces to safely and effectively attack fires from burning onto the Reservation from the Monument or vice versa, both action alternatives have shaded fuel breaks that will be strategically located on roads, private land boundaries and ridges within the project area. Shaded fuel breaks alone, without firefighting efforts, are not intended to stop wildfires. Although the effectiveness of fuelbreaks continues to be questioned because they are constructed to different standards and exposed to a variety of fire weather conditions, a well-designed fuelbreak will alter fire behavior entering the fuel-altered zone (Agee et al. 2000; Cary and Shumann 2003; Ingalsbee 2005; Syphard et al. 2011; RIM FIRE – Preliminary Fuel Treatment Effectiveness Report (USDA, USDI, 2014)). The shaded fuel breaks for this project are designed to alter the fire behavior by reducing fireline intensities, lowering flame lengths and preventing crown fires. The reduced fuel loading is expected to result in increased production rates of fire crews .

Table 1--Current and Recommended Surface Fuels by Fuel Size Class for the Black Mountain Grove

Fuel Size Class (Inches)	Current* (Tons per Acre)	Recommended (Tons per Acre)
Duff	30.1	1-15
0-1	3.1	1-2
1-3	4.4	1-3
3-9	5.0	1-3
>9	94.2	10-20
TOTAL	**91.8**	**14-43**

**** Current refers to the 2003 inventory conditions. Recommendation based on Jump (2002)***

Weather

The project area is best described as an arid Mediterranean climate with dry summers and cool wet winters. Precipitation averages approximately 30 inches per year with approximately half of this as snowfall.

RAWS Data / Fuel Moistures

The weather data that best represents this project area is from the Park Ridge remote automated weather station (RAWS). This RAWS is similar in elevation and has the largest amount of data near this site. The Fire Family Plus 4.0 software program (Bradshaw et al. 2008) was used to determine the 90th percentile weather from 12 years of observations from 1997-2009. See Table 2 for a summary of the 90th percentile weather at the Park Ridge RAWS. The main influences on fire behavior in this area are the diurnal winds associated with the heating and cooling of the San Joaquin Valley, creating up and down canyon winds. Fire weather is significantly affected by low relative humidity and high temperatures during the summer months and in the fall, by very dry easterly winds and winds associated with cold fronts.

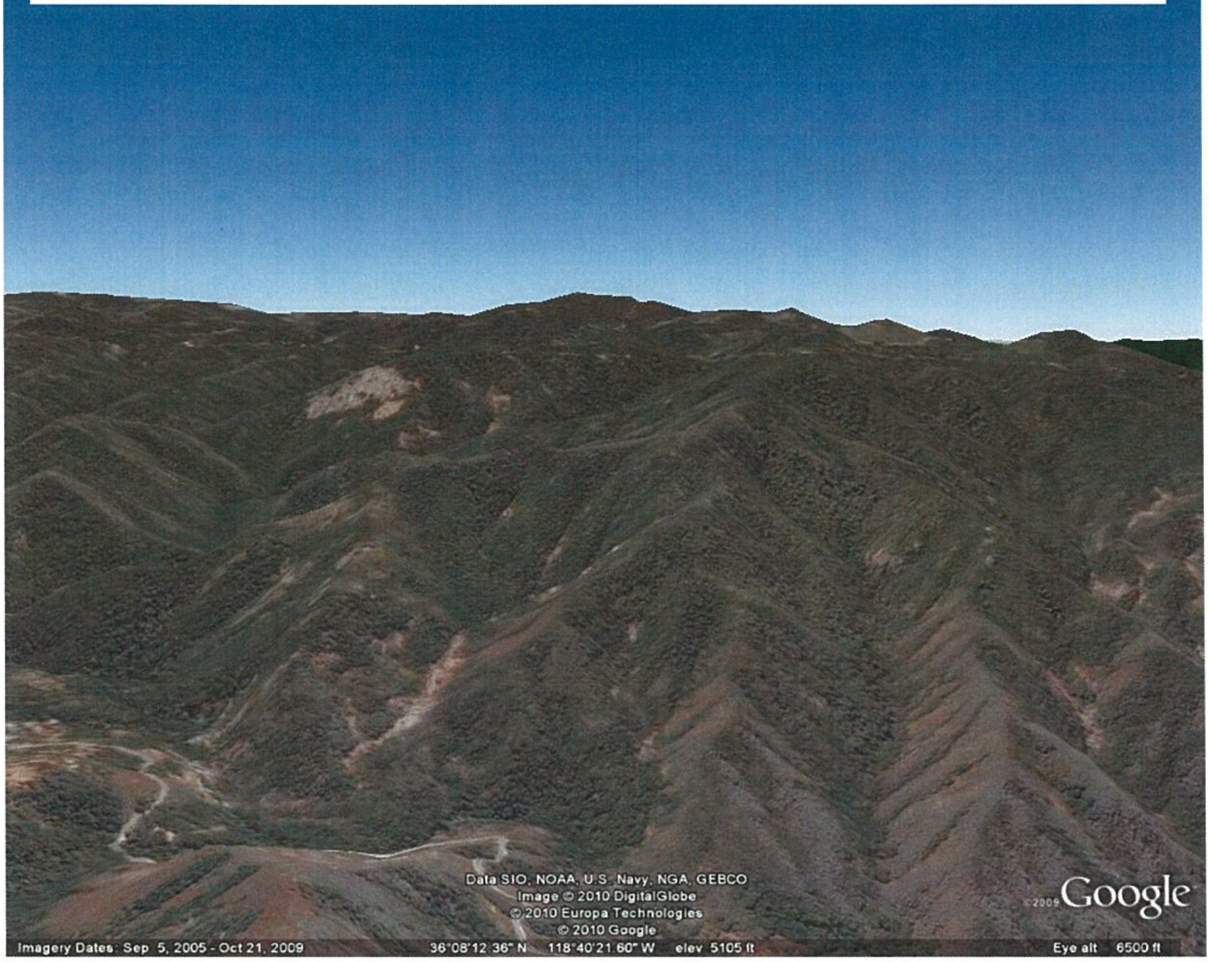
Table 2--90th Percentile Weather conditions for time lag fuels, winds, temperature, and herbaceous and woody fuel moisture at the Park Ridge RAWS

90th Percentile Weather		
1 hour Fuel Moisture	4%	0 to .25 inches in diameter
10 hour Fuel Moisture	4%	.26 to 1 inch in diameter
100 hour Fuel Moisture	6%	1 to 3 inches in diameter
1000 hour Fuel Moisture	7 %	>3 inches in diameter
20 foot wind speed	7 mph	
Temperature	80°F	
Herbaceous Fuel Moisture	30%	
Woody Fuel Moisture	60%	

Topography

The project area and adjacent lands north to the Tule River canyon consist of steep rugged terrain (fig. 2) with many ephemeral and intermittent streams flowing into perennial drainages that feed the Middle Forks of the Tule River. Aspects vary depending on drainage, but the general orientation is northerly. The elevation ranges from 4800 to 7300 feet. The majority of the slopes exceed 30%, with numerous ridges and drainages with a north/south alignment towards the Reservation boundary.

Figure 2--View looking south from Highway 190. The project is generally at the top of the ridge in this image and within the upper third of the slope on north and westerly facing



Fire History / Fire Return Interval

Research in the Giant Forest of the Sequoia and Kings Canyon National Parks, adjacent to the Sequoia National Forest, shows that over three millennia during the warmest and driest periods, the fire return interval was the shortest (Swetnam et al. 2009). Fire-scar studies in giant sequoia groves in Yosemite National Park, Sequoia and Kings Canyon National Parks, and Mountain Home Demonstration State Forest, CA, suggest that mean fire return intervals were as low as 2.5–3 years for more than 1300 years from AD 500–AD 1875. Occasionally, fire-free intervals of 20–30 years occurred in the record (Swetnam et al. 1992; Swetnam 1993). At Cedar Slope only three air miles from the project area, preliminary research by students from Penn State University indicates that the area burned on an average of every 5 years prior to 1910. In the same study, fire scar data collected from the Freeman Creek Grove and the Long Meadow Grove shows a similar frequency of burning. These areas are within 10 air miles of this project's location (Taylor, unpublished data, 2007).

Sequoia National Forest fire history and ignition records for the last 100 years have recorded 11 fires that originated inside the project area, all of which remained less than 10 acres (Table 3).

Table 3--Fire history of the project and surrounding area

Year	1913	1914*	1916	1917*	1919*	1924	1926*	1928*	1964	1969	1976	1983	1984	1987	1994	2007	2008*
Acres	<1	182	<1	77	195	2	27	3,052	<1	<1	<1	<1	4	2	<1	<1	275

*** Fires that originated outside of the project area**

Six fires much larger in size have originated outside the project area and then burned into the project area; the largest fire reaching almost 3,000 acres in 1928 (Table 3 and fig. 3). Factors contributing to these larger size fires appear to be steep inaccessible slopes combined with heavy fuel loading. For fires that originate below the project area, these factors align for extreme uphill fire behavior and large fire growth. These areas also lack safety zones and escape routes for fire fighter safety.

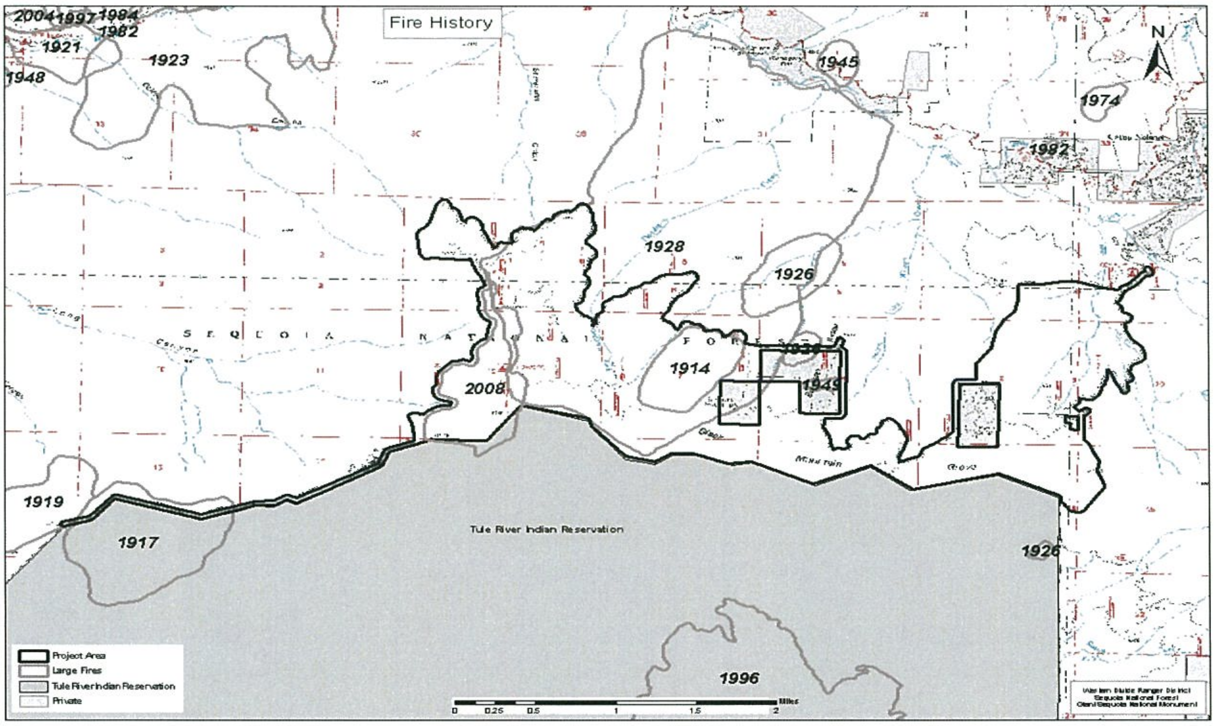


Figure 3--Fire history map of the project area, displaying fires greater than 10 acres

The majority of the fires that have affected this area occurred within the Middle Fork Tule River drainage north and west of the project area. Several other fires have occurred in the South Fork of the Middle Fork (SFMF) Tule River drainage which lies immediately north of the project area. The 1928 fire burned from the confluence of Moorehouse Creek and the SFMF Tule River up to the ridge separating the Tule River Indian Reservation's north boundary and the Monument. The location of the upper portion of the fire perimeter burned near the central portion of the project area (fig. 3). The next largest fire to burn into the project area occurred in 2008 called the Solo 2 fire which burned approximately 275 acres on the Monument with a small portion on the Reservation near the western end of the project area.

The proposed project area and some surrounding areas have deviated from historic fire return intervals of 2.5 to 30 years, primarily due to fire suppression. Former fire and vegetation management has allowed dense stands of trees and shrubs to grow, resulting in the current high fuel loading. Areas with high fuel loading often burn unnaturally, with intense fire behavior. The Black Mountain Grove Inventory report found a buildup of fuels at a higher concentration than is expected within the range of natural variability within giant sequoia groves (Jump 2004). By reducing the surface and ladder fuel amounts with the proposed work, the hazardous fuel loading situation can be mitigated.

Fire Regime Condition Class (FRCC)

Fire regimes are a generalized description of the role fire plays in an ecosystem and characterized by fire frequency, predictability, seasonality, intensity, duration, scale, as well as variability. Condition classes are a function of the degree of departure from historic fire regimes resulting in alterations of key ecosystem components such as species composition, structural stage, and stocking levels. One or more disturbances can cause a departure in fire regimes such as fire exclusion, timber harvesting, insects and disease, and past management activities (Schmidt et al. 2002). There are three condition classes associated with fire regimes:

Condition Class 1: Fire regimes are within historical range of variability and the risk of losing key ecosystem components is low. Vegetation attributes (species composition and structure) are intact and functioning within a historical range.

Condition Class 2: Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical frequencies by one or more return intervals (either increased or decreased), resulting in moderate changes to one or more of the following: fire size, intensity, severity, and landscape burn patterns. Vegetation attributes have been moderately altered from their historic range.

Condition Class 3: Fire regimes have been significantly altered from their historical range. The risk of losing key ecosystem components is high. Fire frequencies have departed from historic frequencies by multiple return intervals resulting in dramatic changes to one or more of the following: fire size, intensity, severity, and landscape burn patterns.

Condition Class 2 and 3 may require higher levels of restoration, by hand or mechanical treatments, to restore the process of fire on a landscape to historical fire regimes (Schmidt et al. 2002). Approximately 92 percent of the project area is in either condition class 2 or 3. Table 4 lists the estimated FRCC for the entire project area for the existing conditions. One goal of the proposed action is to slowly change the condition class trajectory back towards condition class 1. Often this is only accomplished by multiple treatment periods and this project may be viewed as one incremental step toward reaching that goal. FRCC is often viewed on a

Table 4--Fire Regime Condition Class (FRCC) within the project area

Fire Regime Condition Class	Percent of the project area	Percent of Grove
Class I	8	3
Class II	41	48
Class III	51	49

landscape, watershed, or fireshed spatial level; therefore the project area is a subset of a larger fire regime area on the landscape. More information on FRCC is available online at http://www.frames.gov/partner-sites/frcc/about/.

Overview of the Alternatives

Under the No Action Alternative (Alternative 1), no fuel reduction activities would be implemented to accomplish project goals. Two action alternatives have been developed for the project area. Alternative 2 is to reduce surface and ladder fuels on approximately 1,400 acres using a combination of treatments. These treatments include constructing shaded fuel breaks along ridgelines, private land boundaries and road edges; reducing fuels in planted stands; and prescribed burning in a portion of these and additional areas using jackpot burning, pile burning and understory burning techniques. Alternative 3 would treat the same areas as Alternative 2, and add a fourth treatment area of approximately 1,500 acres to further reduce surface and ladder fuels between the planted stands and the fuelbreaks. Some of the fuelbreaks would be narrower than those proposed in Alternative 2 because of the added fuel treatment areas proposed in Alternative 3. See table 5 below for acres of treated areas by alternative.

Table 5--Acres of Treated Areas by Alternative*

Treatment Areas	Alternative		
	1	2	3
No Treatment	2840	1430	15
Planted Stands	0	400	400
Shaded Fuel Breaks	0	730	690
Understory Burn	0	280	240
Other Fuel Treatments [1]	0	0	1,500
Total Area Treated	0	1,410	2,830

* All acres are rounded to the nearest 10.

1. This area is a combination of jackpot and pile burning (an estimated 1,456 acres), only pile and burn methods will be used within the fisher den buffer (approximately 45 acres).

Air Quality

The entire project area lies within the San Joaquin Valley Air Pollution Control District (SJVAPCD) boundaries for Tulare County. Table 6 lists smoke sensitive areas that are near the project area and their locations are displayed on the map in Figure 4. Wind patterns in this area are generally up and down slope winds associated with the Tule River drainage system (diurnal winds) which are affected by heating and cooling in the San Joaquin Valley. Cold fronts in the fall and winter will affect wind patterns over the project area. Inversions can also trap smoke during the night. Past emission readings from air quality monitoring equipment used during burning operations on the Camp Nelson Project and other prescribed fire projects completed in the past in this general area have not produced significant impacts to smoke sensitive areas or exceedence of 24 hour standards.

Smoke Management

This project will have segments that can be burned individually, or if conditions occur to take advantage of optimum burning conditions, more areas can be ignited within the same weather pattern. Target fuels will be dry to consume quickly and limit smoldering. Personnel on site will monitor smoke conditions and mobile monitors (E-BAM) can be requested at smoke sensitive areas as needed.

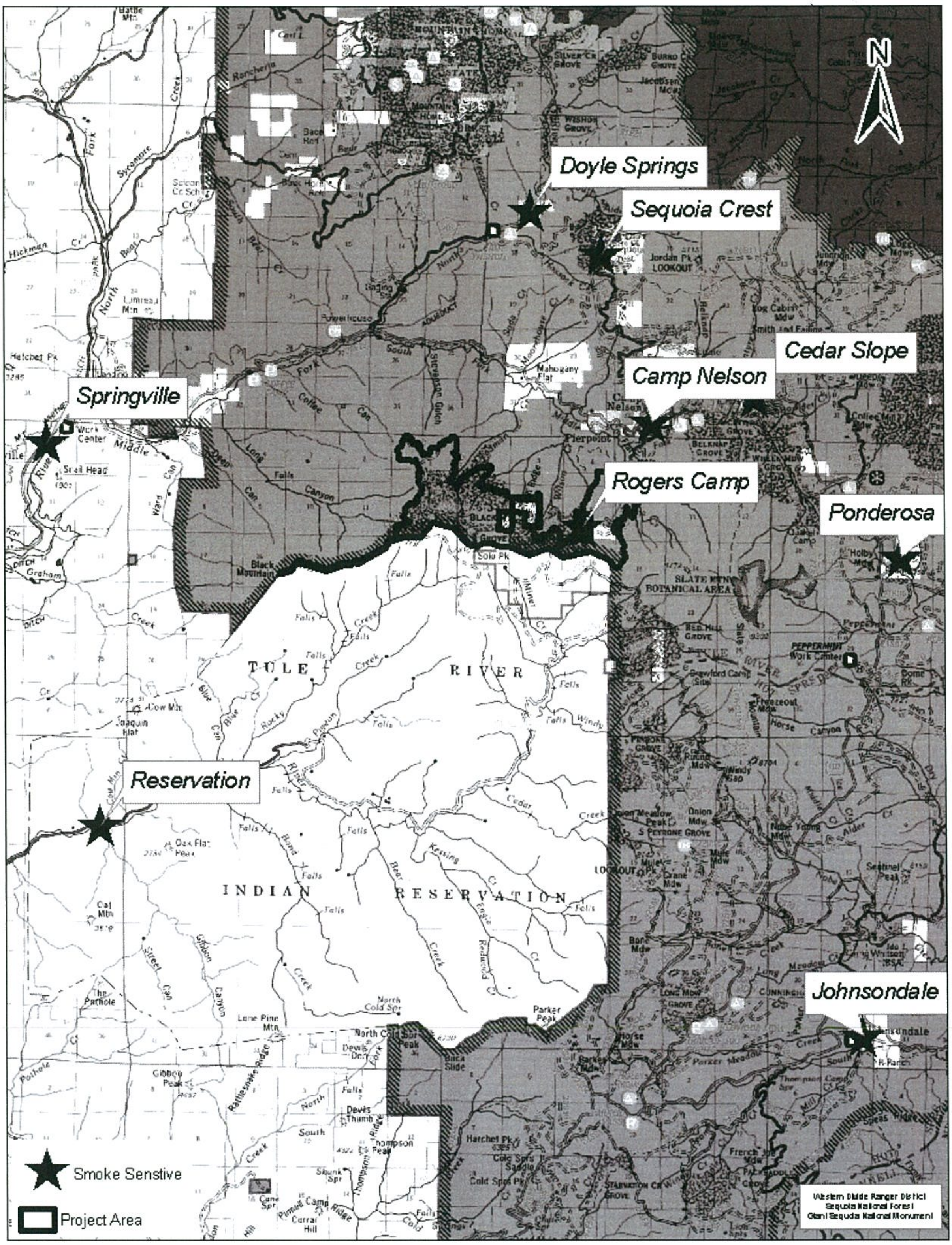
Table 6--Smoke sensitive areas from the center of the project area in air miles and bearings.

Name	Distance (air miles)	Azimuth (degrees)
ROGERS CAMP	0	243
CAMP NELSON	3	214
DOYLE SPRINGS	6	169
SPRINGVILLE	10	100
SEQUOIA CREST	6	188
CEDAR SLOPE	5	233
PONDEROSA	7	269
JOHNSONDALE	11	326
TULE RIVER RESERVATION	8	230

Conformity

The Forest will follow Title 17 of the California Code of Regulation – Subchapter 2, Smoke Management Guidelines for Agriculture and Prescribed Burning and Public Resource Code 4291 – for Hazard Reduction Burning in the foothill and mountain areas of the SJVAPCD. Implementation of prescribed burning will only occur after approval from SJVAPCD. The conformity rule states "that the prescribed burns conducted in accordance with a smoke management program (SMP) which meets the requirements of EPA's Interim Air Quality Policy on Wildland and Prescribed Fires or an equivalent replacement EPA policy" are considered as "presumed to conform." The EPA has approved California's revised Title 17 regulations as an equivalent of a SMP. Therefore, the project will fall under "presumed to conform" for implementing prescribed burning.

Figure 4--Smoke sensitive areas near the project area



Models and Methodology

FlamMap 3.0 fire simulator modeling program (Finney et al. 2004-2006) was used to model the potential fire behavior for the project area. The program calculates fire behavior and environmental variables across a landscape using Geographic Information System (GIS) spatial computer modeling layers, fire behavior fuel models, weather and fuel moistures. Modeling a potential fire across the landscape and project area was completed in the fall of 2009. FlamMap analysis of simulated wildfires in the project area gave measurable results in multiple categories for the two action alternatives. These categories are: flame length, rate of spread, and fire behavior (surface fire, passive crown fire, and active crown fire). Further analysis was conducted using FlamMap on fire flow paths and fire arrival times for each Alternative.

Fire intensity refers to the rate of heat produced by the flaming front of a wildland fire at a point in time and is expressed in British Thermal Units per foot per second (BTU/ft/sec). Fire intensity is influenced by the amount of fuel available for burning, local weather conditions and topography. While there are several ways of expressing fire intensity, fireline intensity is the most widely used. A visual indicator of fire intensity is the flame length (DeBano et al. 1998). Table 7 relates fireline intensity, flame length, and fire suppression difficulty.

Table 7--Fireline Intensity Interpretations*

Intensity	Flame Length	BTU/ft/sec	Interpretations
Low	Less than 4 feet	Less than 100	Direct attack at head and flanks with hand crews, handlines should stop spread of fire
Low-Moderate	4-8 feet	100-500	Employment of engines, dozers, and aircraft needed for direct attack, too intense for persons with hand tools
Moderate	8-11 feet	500-1000	Control problems, torching, crowning, spotting; control efforts at the head are likely to be ineffective
High	Greater than 11 feet	Greater than 1000	Control problems, torching, crowning, spotting; control efforts at the head are ineffective

*Fireline intensity interpretations from DeBano et al. (1998)

The Forest Vegetation Simulator (FVS; Dixon 2010) computer program and the Fire and Fuels Extension (FFE; Rebain 2010) to FVS were utilized for this analysis. FFE simulates fuel dynamics and potential fire behavior over time in the context of stand development and management. Outputs derived from this program were used to predict effectiveness of treatments over time. For each alternative the tree stands were simulated to be treated the first year and then grown for 10 and 20 years post treatment. Modeling outputs provided stand characteristics that were summarized and compared per alternative.

GIS spatial layers were obtained from Landfire (2009) and Sequoia National Forest GIS databases including, fuel models, elevation, aspect, slope, canopy cover, canopy bulk density, canopy base height, infrastructure and vegetation.

Fuel Models

The Standard 40 Fire Behavior Fuel Models (Scott and Burgan 2005) were used for modeling the project area and adjacent lands north to the Tule Canyon. The fire behavior fuel models for existing conditions were downloaded from LANDFIRE (http://www.landfire.gov/ 2007) to represent Sequoia National Monument and Tule River Reservation lands. The Solo 2 fire of 2008 occurred after LANDFIRE data was collected. Fire behavior fuel models within the Solo 2 fire perimeter required adjustment, and observations indicate that the expected fire behavior in 2009 (post fire) inside the perimeter was best represented by fuel model 181.

Fuel model 181 was also used for modeling year 1 through 5 post treatment fuel conditions for this analysis as well (Table 8, Scott and Burgan 2005). After about 5 years of growth, the fuel models are assumed to change to higher loading amounts or fuel models.

Table 8--Fire behavior fuel models for used in FlamMap analysis for pre-treatment and post-treatment simulations.

Pre-Treatment Fuel Models*	Percent of project area	Year 1 through 5 Post-Treatment Fuel Models
90s – Nonburnable	< 1	No Change
102 – low load grass	< 1	No Change
122 – moderate load grass-shrub	1	No Change
141 – low load shrub	< 1	No Change
142 – moderate load shrub	< 1	141
147 – very high load shrub	< 1	141
161 – low load timber-grass-shrub	< 1	181
165 – very high load timber-shrub	71	181
181 – low load conifer litter	9	No Change
185 – high load conifer litter	< 1	181
186 – moderate load broadleaf litter	17	181
187 – large downed logs	< 1	181
188 – long-needle litter	< 1	181

*Fuel Model codes: describe fuels that dictate fire spread, sometimes not the dominant vegetation.

Weather / Fuel Moistures

As stated earlier in this report, the weather data used that best represents this project area is from the Park Ridge remote automated weather station (RAWS). This RAWS is similar in elevation and has the largest amount of data near this site. The Fire Family Plus 4.0 software program (Bradshaw et al. 2008) was used to determine the 90th percentile weather from 12 years of observations from 1997-2009. See Table 9 for a summary of the 90th percentile weather at the Park Ridge RAWS. The main influences on fire behavior in this area are the diurnal winds associated with the heating and cooling of the San Joaquin Valley, creating up and down canyon winds. Weather is significantly affected by low relative humidity and high temperatures during the summer months and in the fall, very dry easterly winds and winds associated with cold fronts. All FlamMap simulations for all Alternatives used the 90th percentile weather based on the Park Ridge RAWS.

Table 9--90th Percentile Weather conditions for time lag fuels, winds, temperature, and herbaceous and woody fuel moisture at the Park Ridge RAWS

90th Percentile Weather		
1 hour Fuel Moisture	4%	< .25 inches in diameter
10 hour Fuel Moisture	4%	.25 to 1 inch in diameter
100 hour Fuel Moisture	6%	1 to 3 inches in diameter
1000 hour Fuel Moisture	7 %	> 3 inches in diameter
20 foot wind speed	7 mph	
Temperature	80° F	
Herbaceous Fuel Moisture	30%	
Woody Fuel Moisture	60%	

Effects of Alternatives

Direct effects of the alternatives are summarized in Table 10 based on comparing the following characteristics: fire intensity (flame lengths), rate of spread, surface and crown fire behavior, firefighter access, crew production rates, and reduction of fire threat. For alternatives 2 and 3, the table shows a higher percentage of project area with flame lengths in the 0-4 and 4-8 foot range because of the reduction of project area with greater than 8 foot flame lengths.

Table 10--Direct effects of the three Alternatives to fire and fuels characteristics averaged throughout the project area

Characteristic	Alt. 1	Alt.2	Alt. 3
Flame Lengths ranging from 0-4 ft.	4%	36%	32%
Flame Lengths ranging from 4-8 ft.	9%	14%	67%
Flame Lengths > 8 ft.	87%	50%	<1%
Rate of Spread: 0-10 chains/hour	42%	69%	96%
Rate of Spread: >10 chains/hour	57%	31%	4%
Rate of Spread: reduced by 50% in Planning Area	No treatment = no reduction	reduced by less than 50%	reduced by 50% and greatest reduction across planning area
Barren (No fire Activity)	0.5 %	0.5 %	0.5 %
Surface Fire Behavior (% Project Area)	14%	55%	95%
Passive Crown Fire (% Project Area)	68%	34%	4%
Active Crown Fire (% Project Area)	17%	10%	1%
Firefighter Suppression Access	Access is poor for existing condition	improved on 1,410 acres	Same as Alt. 2 and an additional 1,500 acres
Crew Production Rates: comparison to pretreatment rate (minimum goal is to double the rate)	No change in rate	more than double rate in shrubs and triple rate in understory	more than triple rate in shrubs and 6 times rate in understory
Fire threat: Acres of treatment between private land and the Reservation	None	Treats private and Reservation land perimeters with shaded fuel breaks	Same as Alt. 2 and treats an additional 1,500 acres

Indirect effects of the Alternatives were grouped into three categories. As mentioned previously, a fire regime refers to the FRCC (NIFTT 2010) rating system based on departure from historically estimated fire regimes across the landscape. Connectivity is a spatial estimate based on location of project area treatments for each alternative in relation to private land, Reservation land, and the Camp Nelson project. Indirect effects for air quality are compared as projected changes to future wildfire emissions. See Table 11 for comparisons of these indirect effects for each Alternative.

Table 11--Indirect effects of the three Alternatives to fire and fuels characteristics averaged throughout the project area

Characteristic	Alt. 1	Alt.2	Alt. 3
Fire Regime Condition Class (FRCC) *	no change, FRCC of 3	closer to historical, FRCC of 1 to 2	closer to historical, FRCC of 1 to 2
connectivity to other land owners or projects	No connectivity to private land, Camp Nelson, nor the Reservation	Some connectivity to Reservation, mostly fuel breaks (corridors) to private land and Camp Nelson Project	same as Alt. 2 plus landscape scale connection to Camp Nelson project
change to future wildfire emissions	no change or increase in emissions	some decrease in emissions	greatest decrease in emissions

* These comparisons are on the spatial level of the project, not the landscape level.

FVS

FVS FFE was used to simulate treatment effectiveness for the 2 action alternatives based on estimated pile burning, understory burning using prescribed fire. Table 12 lists tree mortality and growth modeling based on effects from pile burning and prescribed fire.

Table 12--Average tree mortality from prescribed burning, by size class, treatment area.

Mortality Trees per acre	Alt 1	Alt 2	Alt 3
Trees < 15 in dbh (75% of these are seedlings)	none	26	26
Trees 15-17.9 in. dbh	none	2	2
Trees 18-23.9 in. dbh	none	1	1
Trees 24-29.9 in. dbh	none	<1	<1
Trees 30-34.9 in. dbh	none	<1	<1
Trees ≥ 35 in.dbh	none	<1	<1

Fire Behavior Simulations

Figure 5 illustrates the differences in fire behavior categories for each alternative. No fire was simulated where barren fuel models were represented on the ground (less than 1% of project area). Alternatives 2 and 3 have different amounts of shaded fuel breaks, understory burning, and tree stand treatments. The modeled fire behavior post treatment decreased because fuel loading was reduced resulting in decreased vegetation to fuel future fires. Surface fuel loading reduction treatments included piling and burning, jackpot burning or understory burning. Compared to Alternative 2, Alternative 3 has additional fuel treatments. Alternative 3 has the best improvement in active and passive crown fire because of the greatest reduction in fuel loading based on the most acres proposed to be treated.

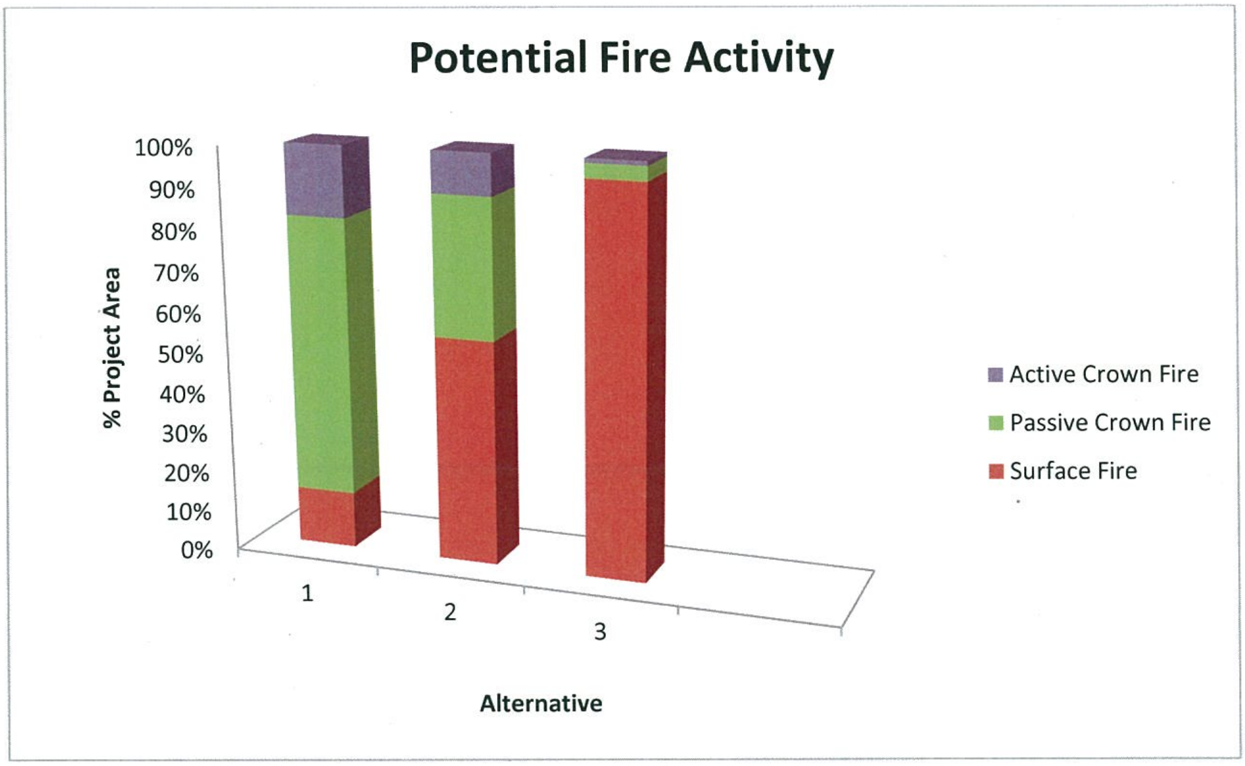


Figure 5--Three fire behavior categories represented graphically for each alternative

The modeled rate of spread was dramatically reduced by the action alternatives (Fig. 6), See Table 10 for a comparison of estimated rate of spread amounts. Both Figure 6 and Table 10 are based estimates from 1 to 5 years post initial treatment time periods, thereafter the live fuels (vegetation) would grow or regenerate to higher levels than listed. The most acres treated within the project area are proposed in Alternative 3; therefore, this alternative has the greatest reduction in rate of spread.

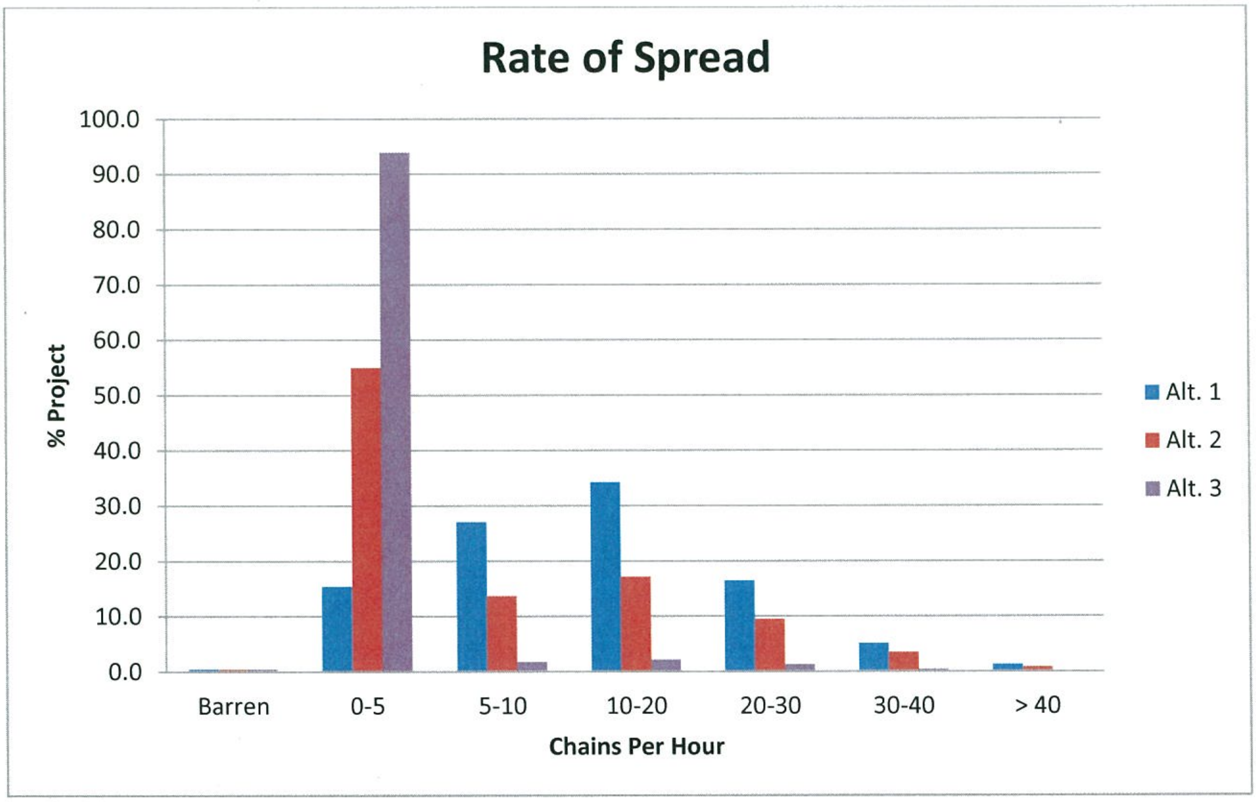
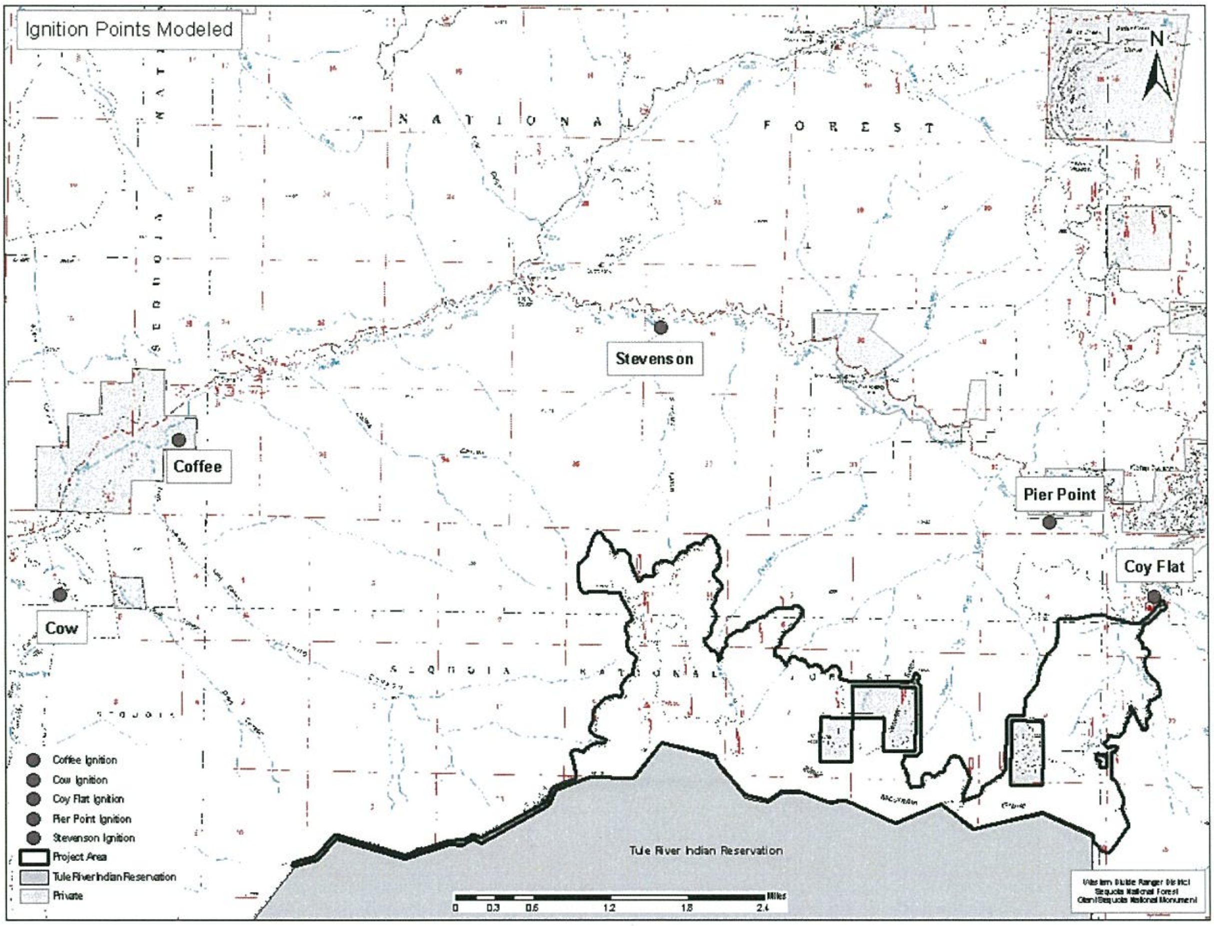


Figure 6--Rate of spread across project area for each alternative modeled for post treatment conditions

Fire Arrival Time/Burn Interval

FlamMap was used to model potential fire arrival time (fire growth) using five ignition points along the lower portion of the Middle Fork and SFMF Tule River drainages (fig. 7). Fire arrival time simulations were utilized as a measurement of simulated fire perimeter growth or fire progression. The change in fire size per burn period is a simulation of fire progression and is displayed in 6 hour intervals for a Stevenson ignition point for each alternative (fig. 8, 9 and 10). The program simulated existing conditions and potential fire behavior after treatments for each alternative. The fire modeling, visually displayed in the burn interval maps, demonstrates that the action alternatives will slow a fire's rate of spread with alternative 3 being the most effective.

Figure 7--Ignition Points used for fire behavior analysis (travel time and flow paths)



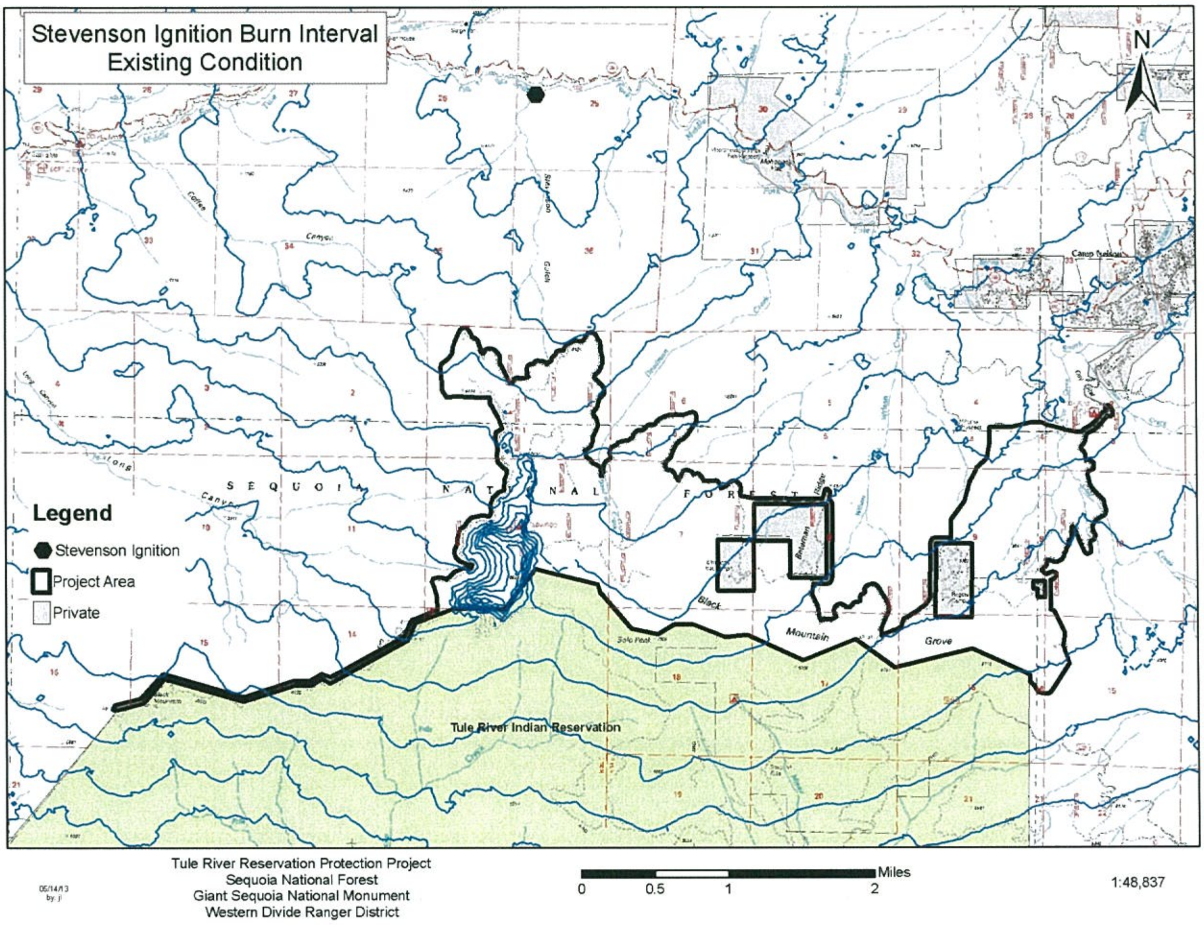


Figure 8--Fire progression for Existing Condition (Alternative 1) shown in 6 hour intervals

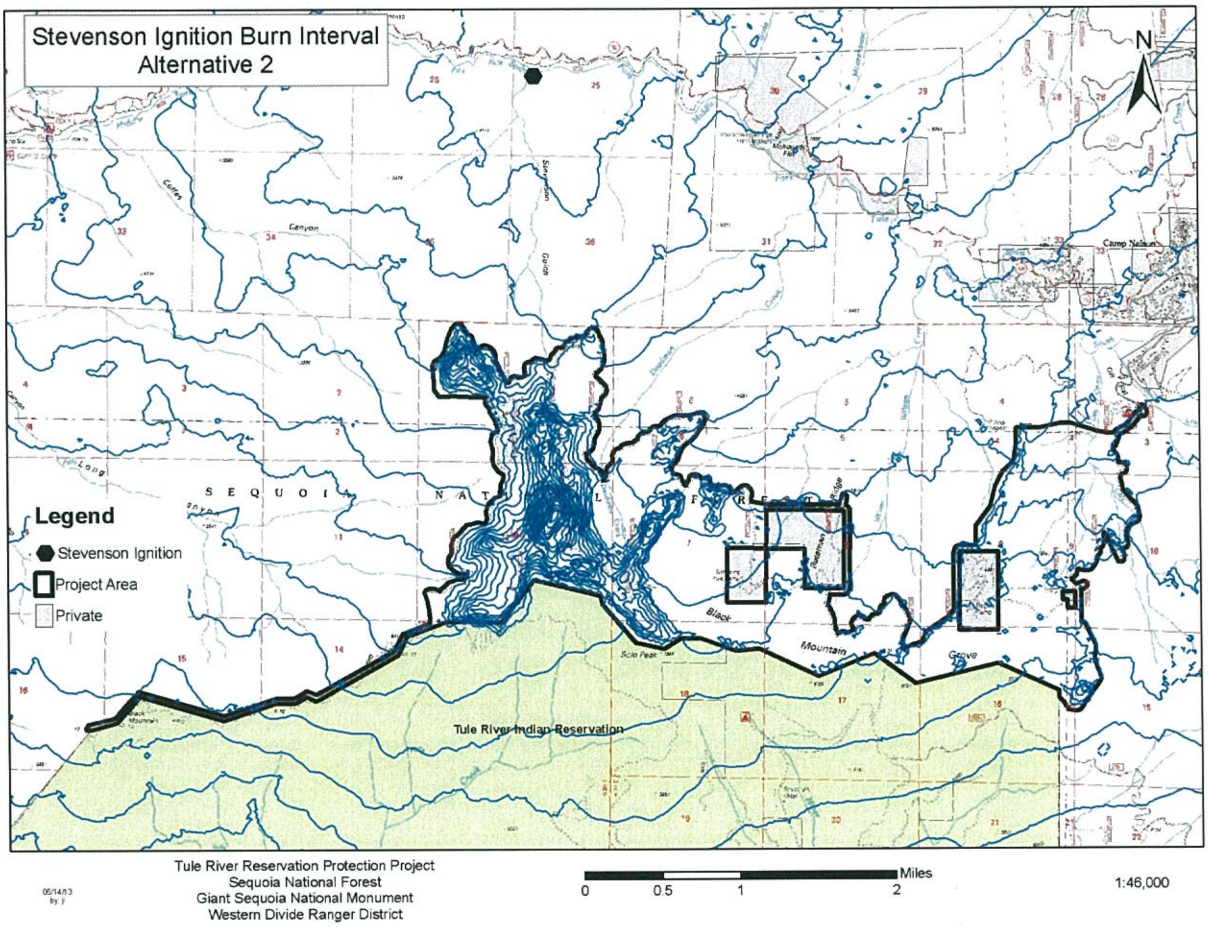


Figure 9--Fire progression for Alternative 2 shown in 6 hour intervals

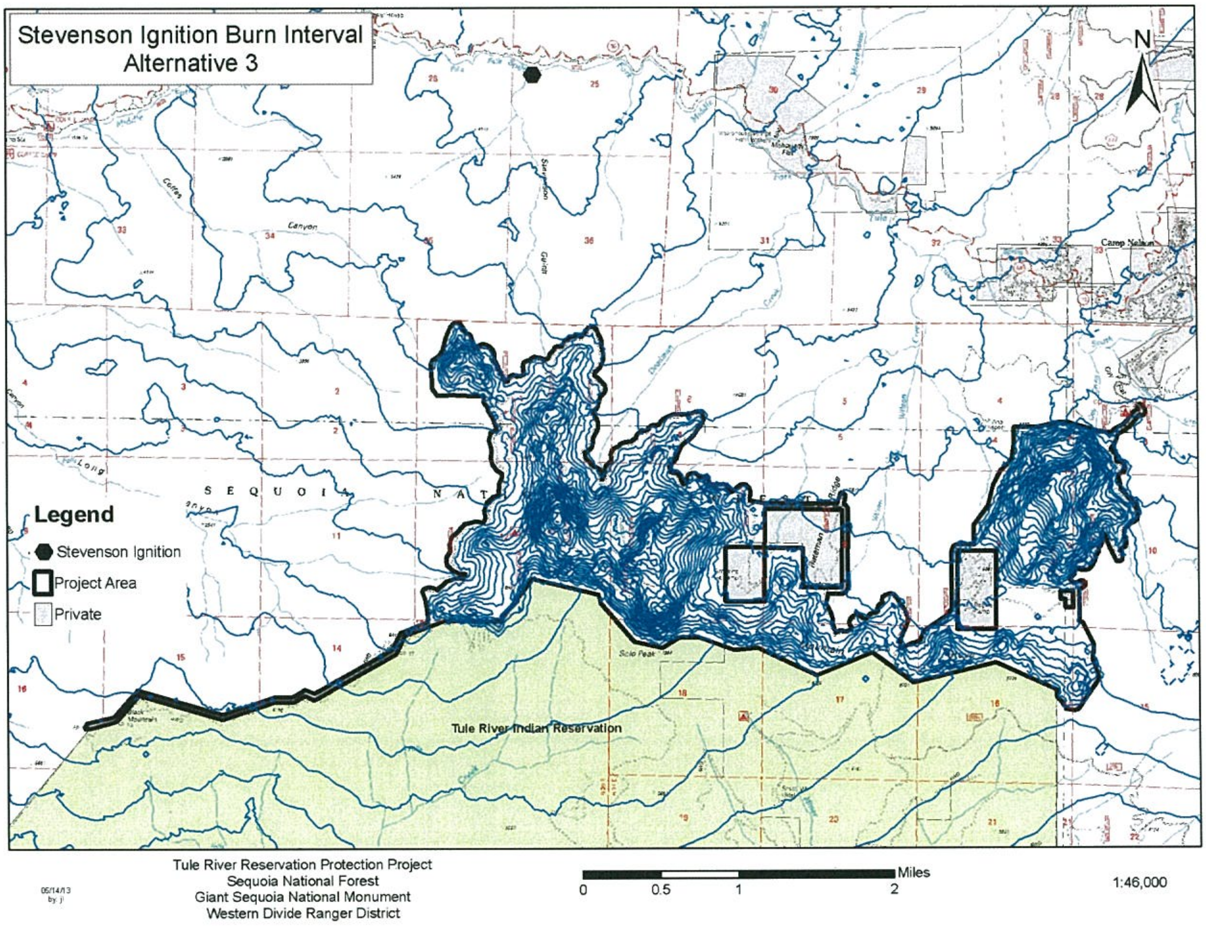
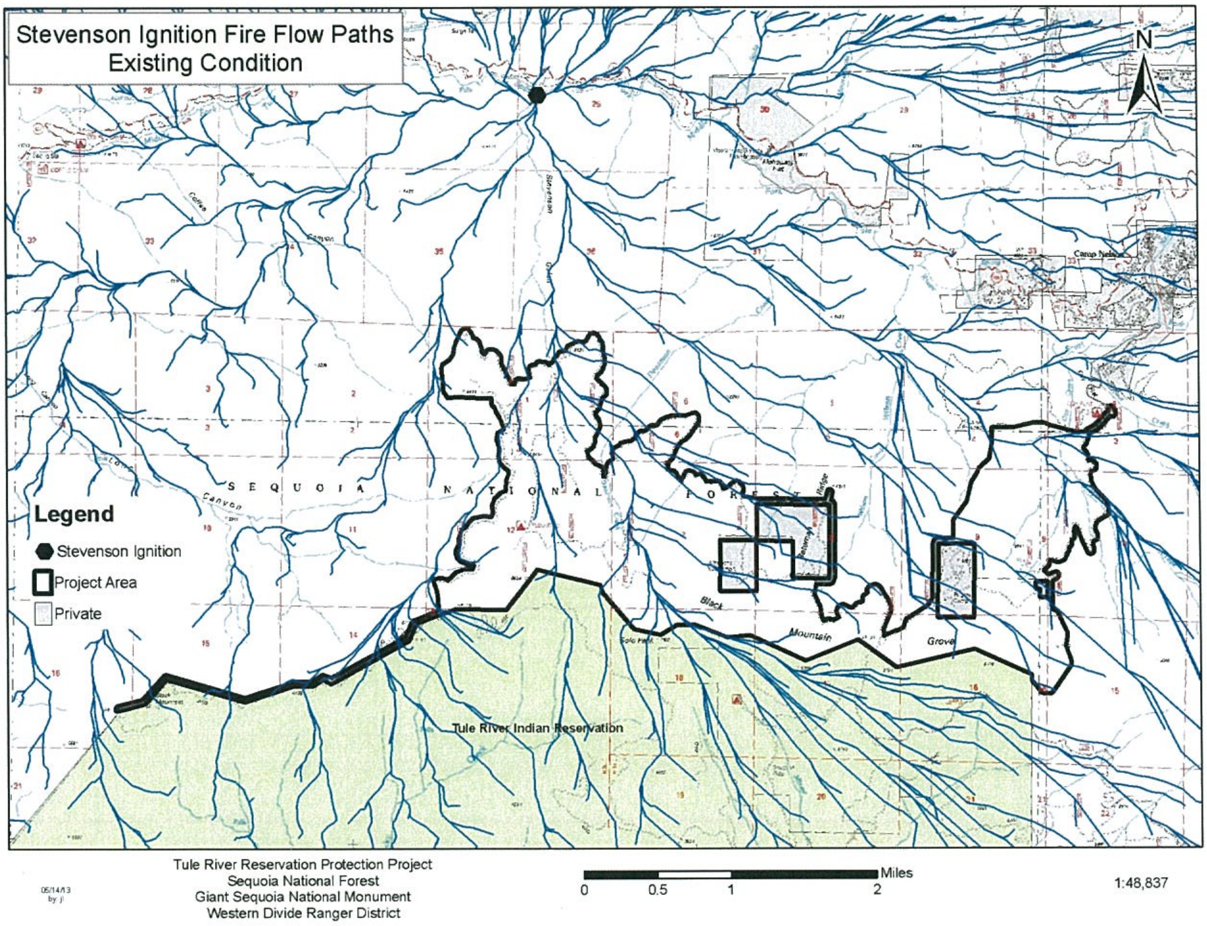


Figure 10--Fire progression for Alternative 3 shown in 6 hour intervals.

Fire Flow Paths

FlamMap was used to model potential fire flow paths using five ignition points along the lower portion of the Middle Fork and SFMF Tule River drainages (fig. 7). Overall, fire flow path analysis illustrated that fires tend to spread south from the ignition points towards the Tule River Reservation. Alignment with drainages enhances and funnels the fire spread. The fire flow paths for the Stevenson ignition point are displayed for each alternative in figures 11, 12 and 13. Only the major flow paths are shown. When all paths are displayed, the output looks much like overlapping feathers with the major flow paths being the shafts of the feathers. The FlamMap fire flow path modeling demonstrates that fire spread, headed south toward the Reservation, would be slowed, stopped or rerouted when fires reach the treatment areas because of the reduced fuel conditions. Some of the fire flow paths run through the project area because they are modeled without suppression activities. A fuel break or fuel reduction project by itself will not stop a wildfire. They provide a location that will increase the probability of success for fire suppression activities such as direct attack or firing out.

Figure 11--Fire Flow Paths for Existing Condition (Alternative 1) from the Stevenson Ignition Point



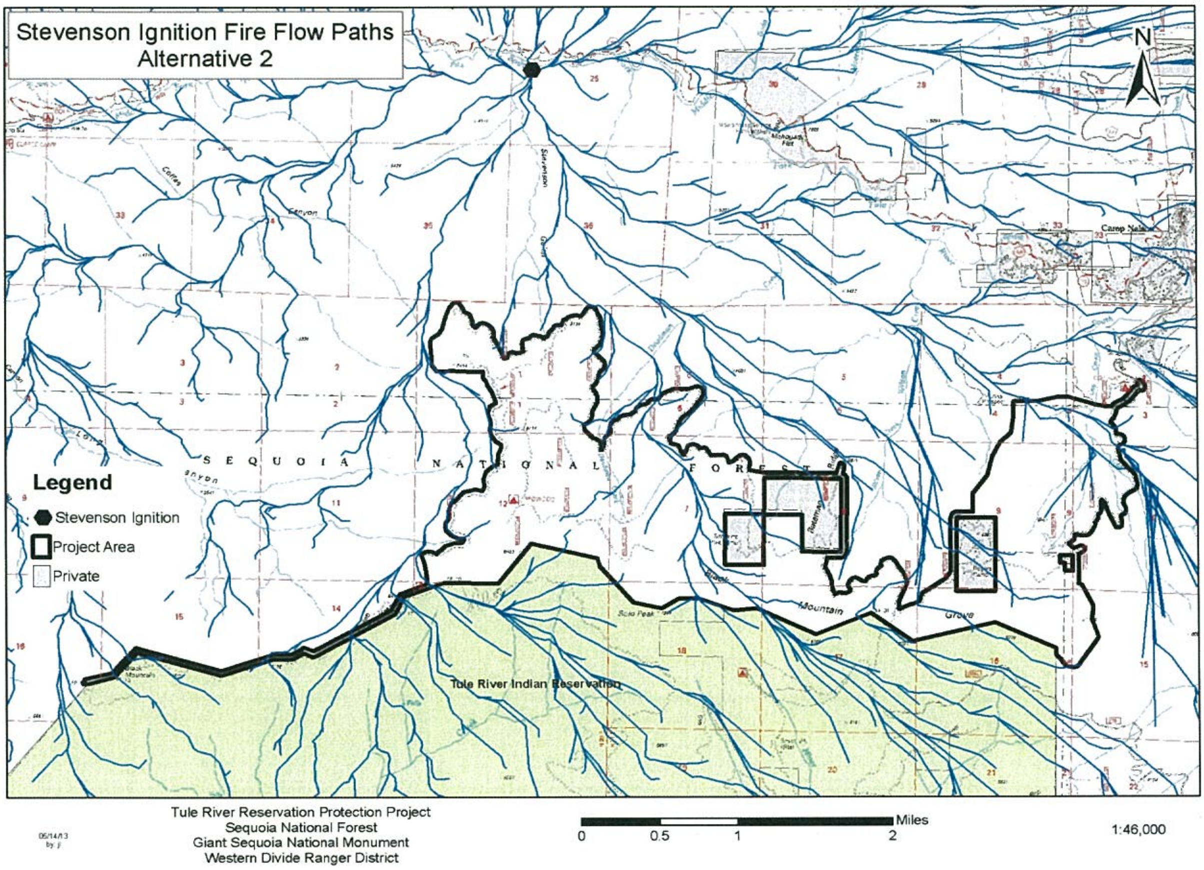


Figure 12--Fire Flow Paths for Alternative 2 from the Stevenson Ignition Point

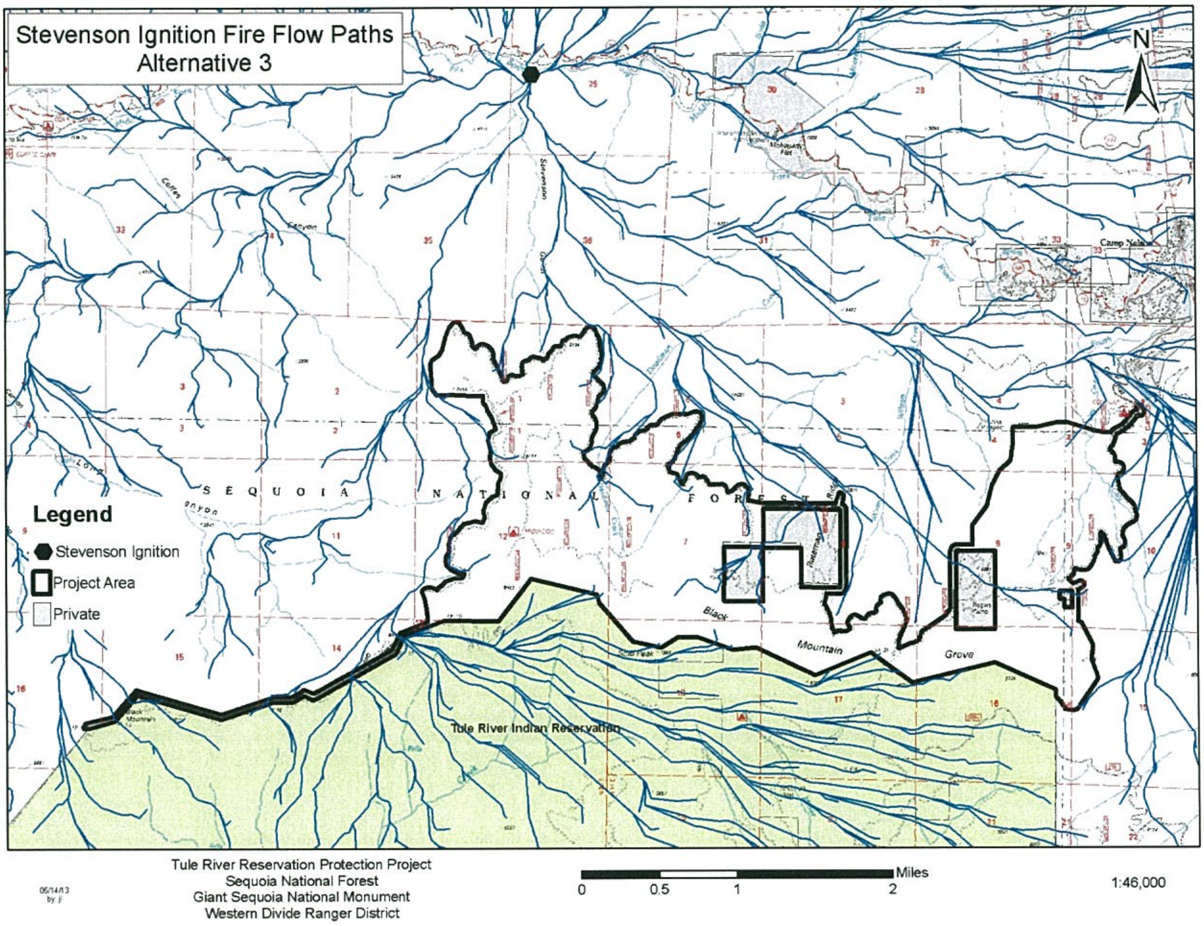


Figure 13--Fire Flow paths for Alternative 3 from the Stevenson ignition point

Fire Line Production Rates

Both of the action alternatives reduce fuel loading, but differ in total acres of fuels reduction treatments. Line construction production rates are directly correlated to fuel loading changes. Reduced fuel loading creates the ability for Type 1 hand crews to construct fire control lines more rapidly. All fuel model changes in the grass category were estimated to have no change, based on annual growth of grass not effecting production rates. Timber understory fuels acres would be treated in timber fuel types, including understory grass, shrub, leaves, and needle cast. For shrub and timber understory, the increases in fireline production rates is based on the amount of acres treated per alternative. See Figure 7 for production rates in the three vegetation categories. Minimum effectiveness is illustrated to show the desired condition of double the production rate of the existing condition.

After the proposed treatments, Alternatives 2 and 3 meet the minimum desired conditions to double fire line production rates compared to pretreatment levels. Alternative 3 would treat an additional amount of acres of shrub (primarily the shrub fields below Rogers Camp that ties into Camp Nelson Project) and timber understory fuels. Alternative 3 has the largest timber understory loading reduction (therefore highest increases in hand line production rates) compared to the other alternatives due to the proposed increase in acres treated in the timber understory fuel models. See Table 11 for more comparisons.

Type 1 crew fire control line production rates are calculated and summarized as a measurement of fuel loading changes. Crew production rates changed based on fuel model changes after treatment. Proposed alternatives were compared based on these crew production rates. Production rates are published in the Fireline Handbook (NWCG 2004) in Appendix A of the General Operational Guides which only use the original set of 13 fuel models. For simple comparisons, both the original 13 fuel models and the Standard 40 Fuel Models were grouped into 3 basic categories: grass, shrub, timber litter/understory. Table 13 lists how the 40 and 13 fuels models correspond to the estimated production rates.

Table 13--Crosswalk - 40 fuel models to 13 fuel models for crew production rates

40 Fuel models	13 Fuel Models	Production Rates in chains per hour	Vegetation Type
102	1	30	Grass
122	2	24	Grass
141	6	6	Shrub
142	6	6	Shrub
147	4	5	Shrub
161	8	7	Timber Understory
165	10	6	Timber Understory
181	8	7	Timber Understory
185	13	5	Timber Understory
186	9	28	Timber Understory
187	13	5	Timber Understory
188	9	28	Timber Understory

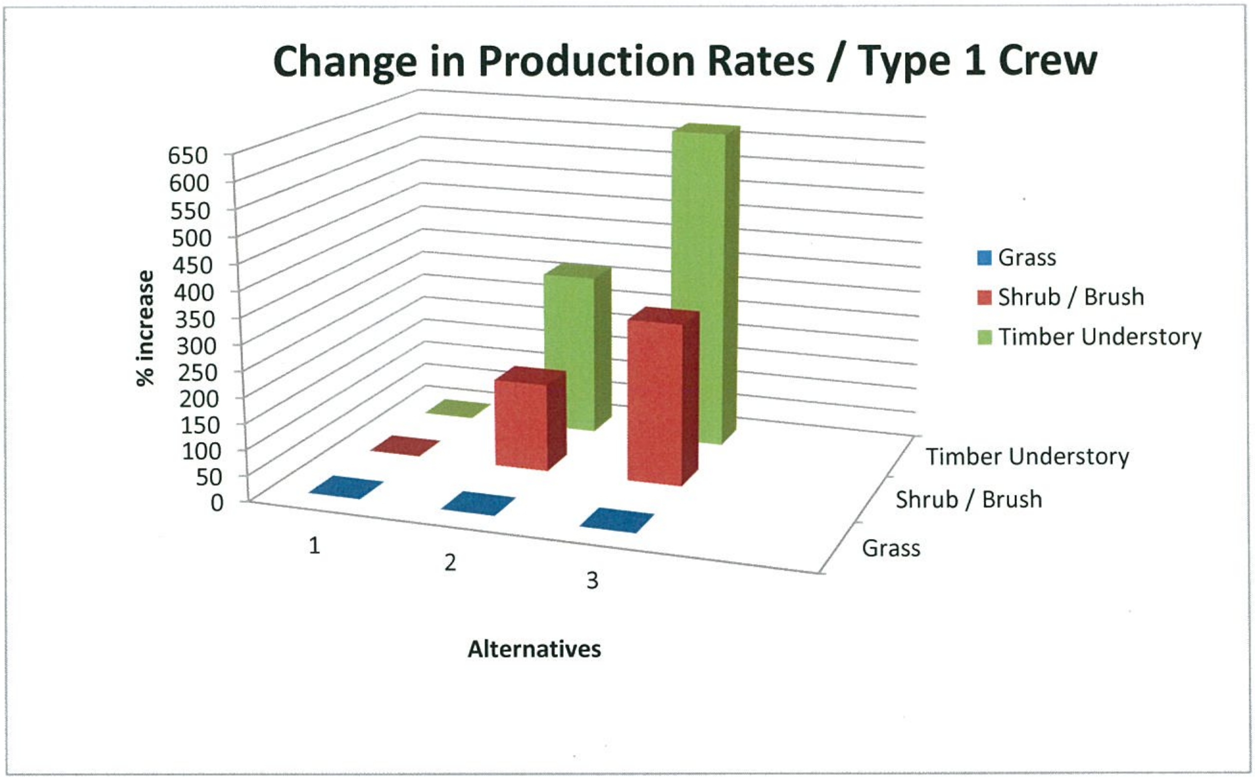


Figure 14--Production rates for Type I hand crew. (100% equals double the production rate of the existing condition). Grass is annual vegetation and no change is expected as it will grow back annually.

Smoke Emission Estimates

Table 14 displays the estimated emissions for each alternative. Emissions were calculated using SJVAPCD emissions reporting spreadsheet. For the no action alternative, the existing condition with no fuel treatment was estimated to burn in a wildfire. Therefore, the emissions for Alternative 1 were estimated to be much higher than the other alternatives. Emissions were calculated for all years of implementation (up to 10 years). Slash piles and prescribed burning emissions were averaged across all acres treated for each Alternative.

Table 14--Emissions Estimates for each Alternative

	Site Information					Emissions					
Alt	**Fuel Type**	**Fire Type**	**Total Acres**	**Tons /acre**	**Total Tons**	**Tons PM10**	**Tons PM2.5**	**Tons NOx**	**Tons SO2**	**Tons VOC**	**Tons CO**
1	Forest	Wildfire	2,840	39	110,760	1,356.8	1218.4	193.8	5.5	803.0	12,904
2	Slash Piles	Prescribed Fire	1,410	17	23,970	93.5	87.5	62.3	0.1	75.5	791
3	Slash Piles	Prescribed Fire	2,830	18	50,940	198.7	185.9	132.4	.25	160.5	1,681

Direct and Indirect Effects Summary

Alternative 1 – No Action

Existing Conditions described previously would continue to exist under the No Action Alternative. Fire severity and intensity would continue to increase as fuel loading continues to naturally increase. If a fire were to occur as modeled, flame lengths would exceed 20 feet in height over 80% of the project area, rates of spread would continue to exceed production rates of crews, 85% of the project area would continue to support passive and active crown fire. Firefighter access in the event of a fire would not be safely provided for and attacking a fire before it spreads to the Reservation would be unlikely. Firefighter access would continue to decline with no treatment of fuels within the project area as fuels accumulate within travel corridors.

Fire regime condition class (FRCC) would continue to remain outside of historic fire return intervals. An increase in surface fuels would occur over time as existing snags, needle cast, and woody debris continue to accumulate. Snag densities are anticipated to increase with naturally and density-related tree mortality. Ladder fuels are also anticipated to increase as regeneration continues and in turn decreasing the average canopy base height within the project area.

Landscape level fuels reduction to protect Tribal lands from catastrophic wildfire would not be provided under this alternative. This alternative creates no direct connections to recently planned or completed fuels reduction projects on the Monument. This alternative does not meet the management direction of the Monument Plan.

Alternative 2

The proposed action primarily consists of treatments along roadsides, ridge lines, private land boundaries, and planted stands of trees within the project area to create access for firefighting personnel to anchor during firefighting operations. Predicted flame lengths, fire line production rates, and crown fire activity within the treated portions of the project area would enhance firefighting effort. Flame lengths in approximately half of the project area, and type 1 crew production rates are met in timber and shrub fuel models. The crown fire potential, both active and passive, would be lowered from 85% of the project area down to 44% based on modeling 90^{th} percentile weather. Firefighting capabilities would be enhanced by the treatments completed within the project area.

Effects associated with this alternative would include the reduction of fuel loading and ladder fuels thus moving the project area toward desired fire regime condition class. Canopy base heights would increase as understory fuels and small trees are removed or burned. This would further reduce the chance of fire spread to the canopy of trees. Work along travel corridors would enhance firefighter access during fire situations. Reducing snags, which pose an eminent hazard for firefighter safety along these corridors, would also occur. Limited connectivity to private land and the Reservation would occur, mostly as shaded fuel breaks and not landscape scale treatments.

Alternative 3

Alternative 3 includes all of the treatments in Alternative 2 and an additional area of surface fuels treatment designed to reduce fuels and risk of fire below Rogers Camp. This alternative meets management direction for flame length, rates of spread and type 1 crew production rate in both shrub and timber fuel models. Fire modeling has shown that greater than 95% of the project area would remain a surface fire after treatment.

All effects associated with Alternative 2 would occur with Alternative 3. The number of acres moved toward desired fire regime condition class would increase to approximately 2,830. An additional indirect effect is the increased connectivity to the Camp Nelson Fuel Reduction Project. Snags greater than 15 inches would be removed if they pose an imminent threat to personnel implementing treatments. This alternative would have the greatest improvement to reduce fire threat because it treats the most acres treated between Forest Service and private or Reservation land, and this landscape scale treatment plan creates the largest improvement in public and firefighter access and safety.

Cumulative Effects

The cumulative effects analysis area for this analysis is south of the Tule River Canyon and north of the Reservation boundary. The eastern boundary is Slate Mountain and the western boundary is the forest boundary. This is the area of concern from a fire and fuels stand point. The last 20 years and upcoming 20 years will be the primary focus for actions and events because the growth of vegetation typically negates fuels reduction/changes within 20 years of fuel reduction, wildfire, and prescribed fire. It is assumed that private property owners would continue to complete minimum requirements to meet state laws for defensible space. However this is not sufficient for reducing fire behavior to a level that protects the Reservation improves firefighter safety or assists the area towards the desired fire regime condition class.

Most past actions related to fire and fuels within this analysis area have occurred long ago so as to be considered ineffective, with two exceptions: the 2008 Solo 2 wildfire and the recently completed Camp Nelson Project. The Camp Nelson Project reduced surface and ladder fuels by thinning trees up to 10 inches dbh, and contributes towards desired conditions. Over time, the vegetation within the Camp Nelson Project will continue to grow and will gradually become an ineffective fuels treatment. Outside of the Camp Nelson Project, the vegetation is overgrown and flame lengths would exceed desired conditions of current management direction. Planted tree stands within the project area are overgrown with brush, tightly spaced trees, and limbs growing near the forest floor.

The Tule River Reservation has been working on a similar project on Tribal lands immediately south of this project. The original request for the TRRP project submitted by the Tribe under the authority of the Tribal Forest Protection Act of 2004 recognized that it could be complementary to their project. The Reservation has been doing fuel treatments south of this project along the NFS and reservation boundary for the past several years. Their work combined with fuel treatments on the NFS side of the boundary would create an effective zone for stopping a wildfire originating from either side of the boundary.

No Action Alternative (Alternative 1)

Under this alternative current fuel loading conditions will continue to degrade. The shade tolerant tree species would continue to multiply; these trees provide the ladder to move fire into the crowns of the larger trees. The high level of surface fuels would continue to exist and be expected to increase with no actions to reduce these conditions. In these conditions current and future wildfires are expected to exceed capabilities of ground fire fighters to control the spread of the fire.

Without fuel reduction treatments a wildfire burning in the existing conditions would be a high risk management incident. High risk fire management activities make it difficult to achieve multiple resource benefits for the ecosystem and the landowners. The safety risk for fire fighters and the public is high due to current heavy fuel loadings. The risk level will continue to grow in the future as fuel loading continues to increase with no treatment action. Alternative 1 does not complement private landowner treatments as compared to Alternatives 2 and 3 as outlined in this document. No improvement to the defense of tribal land is achieved by Alternative 1 (no action).

Short term smoke emissions would be low because no burning would occur in Alternative 1until the occurrence of a wildfire. Over the long term, a wildfire is likely in the future and a large increase of emissions from smoke during a wildfire would be expected. (Schmidt et al. 2002). With no treatment action, the ability to manage wildfires and prescribed fires to achieve fuel management and other resource objectives would be nearly infeasible due to current fuel loading and forest stand characteristics that result in the potential for extreme fire behavior.

Action Alternatives 2 and 3

The action alternatives provide some connectivity to the Camp Nelson Project to the north and east by fuel breaks and travel corridor treatments that would enhance capabilities and safety of firefighting forces. The connectivity of this project with the Camp Nelson Project and Solo 2 wildfire area would provide strategic locations for wildfire suppression and prescribed burning operations in the future. This connectivity will also provide a strategic break in the continuity of fuels across the landscape, slowing the rate of spread and reducing flame lengths of wildfires moving up the Tule River Canyon and upslope towards the Reservation (Finney 2002). Thus the impact of the project reaches beyond the actual ground treated to limit fire spread throughout the lower Tule River Canyon.

Treatments proposed in Alternatives 2 and 3 would complement the adjacent fuel reduction work of home owners and the Reservation by increasing the safety ratio linking adjacent property and USFS activities spatially. Alternative 3 treatments include an additional 1400 acre block of land that consists of surface fuel treatments between the shaded fuel break corridors on the south side of Camp Nelson. See Figures 8 and 10 for comparison maps of fire spread in this area if Alternative 3 was implemented as compared to the existing condition. Networks of fuel reduction activities on the landscape create a vegetation framework that can support fire management activities that achieve multiple resource benefits.

Over the short term smoke emissions would be greater under the action alternatives due to pile, jackpot, and prescribed burning. However, over the long term smoke emissions from future wildfires would be reduced. After modeling different stand structures of Sierran mixed-conifer forest grown over 100 years, including those produced by fuel treatments, it was found that a low density forest dominated by large pines are the most resilient to wildfire, sequestered the most carbon, and had the lowest carbon dioxide emissions (North et al 2009). An analysis of different fuel treatments found understory thinning combined with prescribed burning will have the greatest reduction in potential wildfire severity without severely reducing carbon stocks (North et al 2009). Cumulative smoke produced by prescribed burning and low intensity fires resulting from fuel reductions is less than smoke produced by high intensity wildfires that could occur where no fuel reductions have taken place.

The likelihood of future prescribed fire or wildfires to be managed to benefit multiple resources increases in action alternatives, proportionally with acres of land treated, because of the reduced fuel loading and vegetation structure changes. Alternative 3 has the longest overall time period where stand conditions would permit use of prescribed or managed fire in the future.

Action alternatives 2 and 3 incrementally move the project area towards a desired FRCC, towards condition class 1, with Alternative 3 moving the most acres towards this goal. For example, the Solo 2 Fire moved 8% of the project area towards this goal as an indirect result of a wildfire.

Citations:

Agee, James K., et al. "The use of shaded fuelbreaks in landscape fire management." Forest ecology and management 127.1 (2000): 55-66.

Bonnicksen, T., and Stone, E. 1982. Reconstruction of a Pre-settlement Giant Sequoia-mixed Conifer Forest Community Using the Aggregation Approach. Ecology 63:1134-1148.

Bradshaw, L. Systems for Environmental Management (SEM), and Programming by Stuart Brittain. 2008. Fire Family Plus Version 4.0.2 [Computer program]. Rocky Mountain Research Station's Fire Sciences Laboratory and SEM in Missoula, Montana. Available online: www.fire.org.Carey, Henry, and Martha Schumann. "Modifying Wildfire Behavior-The Effectiveness of Fuel Treatments." The Forest Trust (2003): 16.

DeBano, L.F., Neary, D.G. , and Folliott, P. F. 1998. Fire's Effects on Ecosystems. John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012.

Dixon, G. E. 2010. Forest Vegetation Simulator [computer program]. USDA Forest Service, Forest Management Service Center, Fort Collins, CO. Available online: http://www.fs.fed.us/fmsc/fvs/index.shtml [Accessed Sept. 21, 2010].

ESRI Inc.1999-2006. ESRI ArcMap 9.2. [Computer program] license type: ArcInfo. More information available online at: www.esri.com.

Finney, M. A. 2002. Fire growth using minimum travel time methods, Can. J. For. Res. 32 (2002) (8), pp. 1420–1424.

Finney, M., Britten, S., Seli, R. Copyright 2004-2006. FlamMap ver. 3.0. Fire Sciences Lab and Systems for Environmental Management, both of Missoula, Montana. Available online at: http://www.firemodels.org/content/view/69/83/

Jump, L. 2004. Black Mountain Giant Sequoia Grove Inventory. Porterville CA: U.S. Dept. of Agriculture, Forest Service.

Kilgore, B., and Sando, R. 1975. Crown-Fire Potential in Sequoia Forest After Prescribed Burning. Forest Science 21, 83-87.

Kilgore, B. 1973. The ecological role of fire in Sierran conifer forests.

Quaternary Research 3: 496-513.

Landfire data products retrieved 12/2009. The National Map LANDFIRE: LANDFIRE. 2009. National Existing Vegetation Type layer. U.S. Department of Interior, Geological Survey. Available: http://www.landfire.gov/ [Accessed 12/2009].

McKelvey, K., Skinner, C., Chang, C., Et-man, D., Husari, S., Parsons, D., Van Wagtendon, J., and Weatherspoon, C. 1996. An Overview of fire in the Sierra Nevada. In: Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options: Davis: University of California, Centers for Water and Wildland Resources.

National Interagency Fuels, Fire, and Vegetation Technology Transfer (NIFTT). 2010. Interagency Fire Regime Conditon Class (FRCC) guidebook. Available online: http://www.frames.gov/partner-sites/frcc/frcc-guidebook-and-forms/[Accessed July 2013].

National Wildfire Coordinating Group (NWCG). 2004. Fireline Handbook, NWCG Handbook 3, NFES #0065. Prepared by: Incident Operations Standards Working Team.

North, Malcolm, et al. "An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests." (2009).

Parsons, D. and DeBenedetti, S. 1979. Natural Fire in Sub-alpine Meadows – Case Description From the Sierra-Nevada. Journal of Forestry 77, 477-479.

Rebain, S. A. comp. 2010 (revised July 6, 2010). The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 361p.

Schmidt, K., Menakis, J., Hardy, C., Hann, W., and Bunnell, D. 2002. Development of Coarse-Scale Spatial data for Wildland Fire and Fuel Management. Fort Collins, CO: U.S. Dept. of Agriculture, Forest Service. GTR RMRS -87.

Scott, J., and Burgan, R. 2005. Standard Fire Behavior Fuel Models: A comprehensive Set for Use with Rothermel's Surface Fire Spread Model. Fort Collins CO: U.S. Dept. of Agriculture, Forest Service. GTR RMRS-GTR-153.

Skinner, C. and Chang, C. 1996. Fire Regimes, Past and Present. In: Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options: Davis: University of California, Centers for Water and Wildland Resources

Stephens, S. 1998. "Evaluation of the effects of silvicultural and fuels treatments on potential fire behavior in Sierra Nevada mixed-conifer forests". Forest Ecology and Management 105, 21–35.

Swetnam, T. W., Baisan, C., Caprio, A., Touchan, R., and Brown, P.. 1992. Tree-ring reconstruction of giant sequoia fire regimes. Final report on Cooperative Agreement No. DOI 8018-1-0002 to U.S. Department of the Interior National Park Service, Sequoia and Kings Canyon National Parks, California, USA.

Swetnam, T. W. 1993. Fire history and climate change in giant sequoia groves. Science 262:885–889.

Swetnam, T.W., C.H. Baisan, A.C. Caprio, P.M. Brown, R. Touchan, R.S. Anderson, and D.J. Hallett. 2009. Multi-millennial fire history of the Giant Forest, Sequoia National Park, California, USA. Fire Ecology 5(3): 120-150. DOI: 10.4996/fireecology.0503120

Syphard, Alexandra D., Jon E. Keeley, and Teresa J. Brennan. "Factors affecting fuel break effectiveness in the control of large fires on the Los Padres National Forest, California." International Journal of Wildland Fire 20.6 (2011): 764-775.

Tribal Forest Protection Act of 2004, Public Law 108–278—July 22, 2004. Retrieved at: http://www.fs.fed.us/spf/tribalrelations/documents/policy/statutes/public_law_108-278.pdf

Valliant, N.M., J. Fits-Kaufman, A.L. Reiner, E.K. Noonan-Wright, and S.N. Dailey. 2009. Effect of fuel treatments on fuels and potential fire behavior in California, USA, national forests. Fire Ecology 5(2): 14-29.

Van Wagtendonk, J. W. 1985. Fire suppression effects on fuels and succession in short fire interval wilderness ecosystems. In: Lotan, J. E. et al. (eds). Proc. – symp. And workshop on wilderness fire. U.S. Dept. of Agriculture, Forest Service GTR. INT-182. pp 119-126.

USDA Forest Service. 2008. Black Mountain Fuels Evaluation. Sequoia National Forest and Giant Sequoia National Monument. Available online: http://www.fs.fed.us/r5/sequoia/gsnm/msa_fuels_black_mtn.pdf

USDA Forest Service. 2001. Sierra Nevada Framework Record of Decision, Appendix A. Available online: http://www.fs.fed.us/r5/snfpa/library/archives/rod/appendix_a.pdf

USDA Forest Service, Pacific Southwest Region, Stanislaus National Forest and USDI National Park Service, Pacific West Region, Yosemite National Park. 2014. RIM FIRE – Preliminary Fuel Treatment Effectiveness Report. https://grandfatherrestorationproject.files.wordpress.com/2014/07/rim-fire.pdf